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EVALUATION OF AMF SWIMASTER MR12-II SCUBA REGULATOR.(U)

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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 9-77

EVALUATION OF AMF SWIMMASTER MR12-II SCUBA REGULATOR

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GOLDEN ANNIVERSARY 1927-1977

EXPERIMENTAL DIVING UNIT

UNITED STATES NAVY

PANAMA CITY, FLORIDA 32407

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
Panama City, Florida 32407

NAVY EXPERIMENTAL DIVING UNIT

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6 EVALUATION OF AMF SWIMASTER
MR12-II SCUBA REGULATOR,

10 JAMES R. MIDDLETON

11 MAY 1977

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9 Test rept.,

Approved for public release; distribution unlimited

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ✓ 9-77	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Evaluation of Swimaster MR12-II Scuba Regulator		5. TYPE OF REPORT & PERIOD COVERED Test Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. R. Middleton		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Navy Experimental Diving Unit ✓ Panama City, Florida 32407		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE May 1977
		13. NUMBER OF PAGES 27
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

MR12-II Scuba Regulator
Breathing resistance
Breathing cycle
Inhalation
Exhalation
Breathing Work
Tidal volume
Respiratory minute volume (RMV)
Breaths per minute (BPM)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The AMF Swimaster MR12-II single-hose, demand scuba regulator was tested by the Navy Experimental Diving Unit in accordance with MIL-R-24169A. The tests showed that the MR12-II is an easily operated breathing apparatus requiring low work rates. The MR12-II regulator is recommended for placement on the list of equipment authorized for Navy use.

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LIST OF ABBREVIATIONS

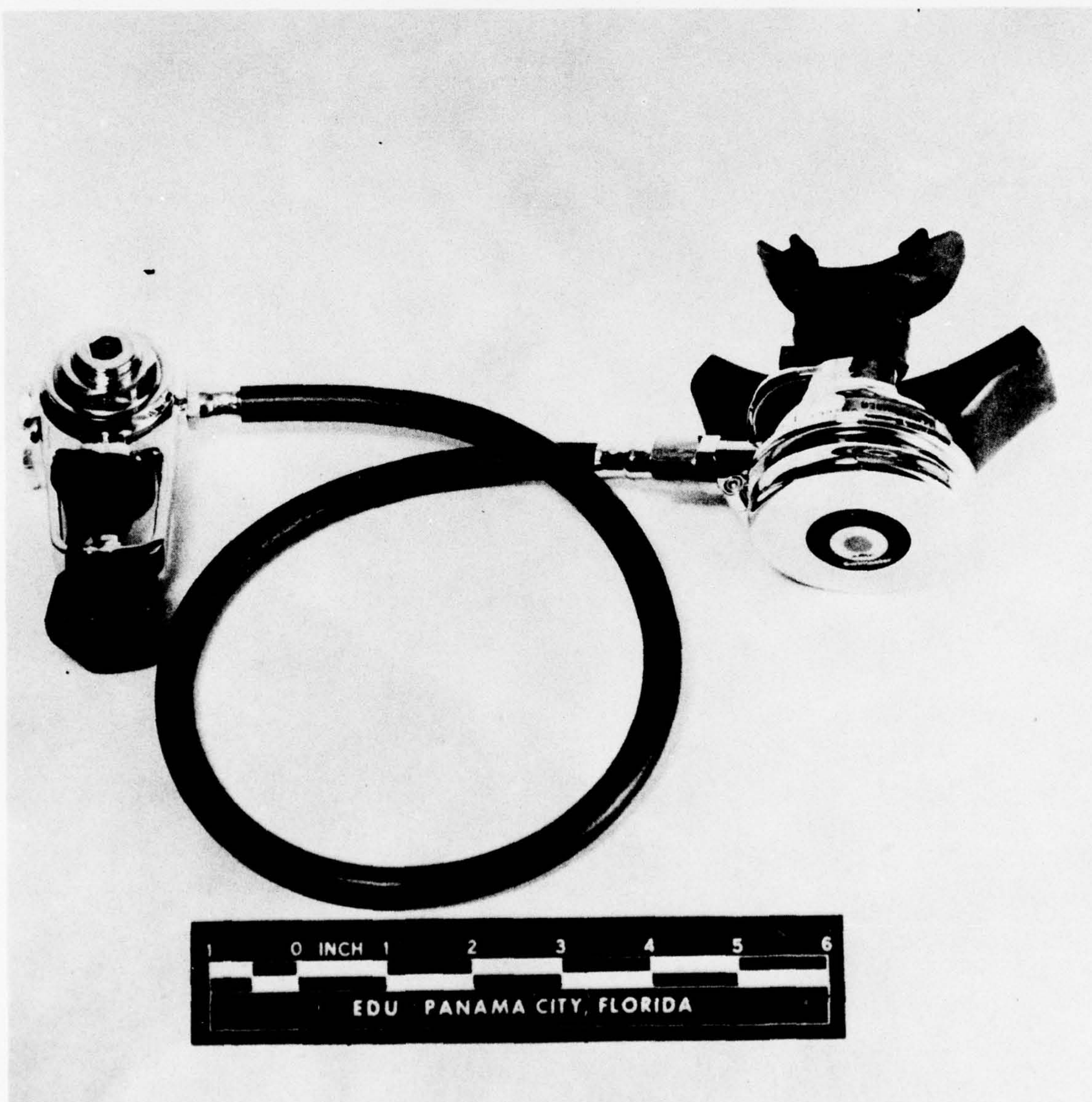
ABBREVIATION	DEFINITION
BPM	breaths per minute
cm H_2O	centimeters of water pressure (differential)
fsw	feet of seawater
kg·m/l	breathing work in kilogram meters per liter ventilation
mil spec	military specification MIL-R-24169A
NEDU	Navy Experimental Diving Unit
O/B	over bottom pressure
psig	pounds per square inch gauge
ΔP	pressure differential
RMV	respiratory minute volume in liters per minute

ABSTRACT

The MR12-II single-hose, demand scuba regulator manufactured by AMF Swimaster was tested by NEDU in October 1976.

A unique bypass tube distinguishes the MR12-II from its predecessor, the MR12. This bypass tube and a deflector baffle mounted in the mouthpiece create a high-velocity, low-pressure area (vortex) in the mouthpiece that effectively reduces inhalation resistance.

The MR12-II regulator, an easily operated breathing apparatus requiring low diver work rates, is recommended for placement on the list of equipment authorized for Navy approval.



AMF SWIMASTER MR12-II SCUBA REGULATOR
(VORTEX-ASSISTED MODEL)

INTRODUCTION

In October 1976, NEDU tested the MR12-II single-hose, demand scuba regulator manufactured by AMF Swimaster, 3801 South Harbor Blvd., Santa Ana, California 92704.

The regulator was tested in accordance with MIL-R-24169A (reference 1). In addition, the regulator was tested at various RMV's to simulate light and heavy work rates. Intermediate pressure between the first and second stages was monitored to measure first stage performance, and breathing work required to operate the regulator was measured to assist in regulator evaluation.

Test results show that the Swimaster MR12-II meets mil spec requirements. The MR12-II scuba regulator is recommended for placement on the list of equipment authorized for Navy use.

TEST PROCEDURE

TEST PLAN

NEDU test equipment was set up as shown in Figure 1. All testing of the Swimaster MR12-II Regulator was in accordance with the applicable mil spec. The detailed test plan is shown in Appendix A and the test equipment required for the tests is listed in Appendix B. A breathing machine simulated inhalation and exhalation at various depths and diver work rates with the following parameters controlled, measured, computed, and plotted.

CONTROLLED PARAMETERS

The following parameters were controlled during the regulator tests.

1. Breathing rate/tidal volume
   a. 15 BPM/1.5 liters 22.5 RMV
   b. 20 BPM/2.0 liters 40.0 RMV
   c. 25 BPM/3.0 liters 75.0 RMV
2. Exhalation/inhalation time ratio: 1.10:1.00.
3. Breathing waveform: modified sinusoid.
4. Air supply pressure: 1000 psig at all depths except 0 fsw and 200 fsw where data were recorded at 1000 psig, 500 psig O/B (overbottom pressure), and 200 psig O/B.
5. Depth increment stops: 0 to 200 fsw in 33-fsw increments and 300 fsw.

MEASURED PARAMETERS

The following parameters were measured during the regulator tests.

1. Inhalation peak ΔP (cm H_2O).
2. Exhalation peak ΔP (cm H_2O).
3. ΔP vs. tidal volume plots.

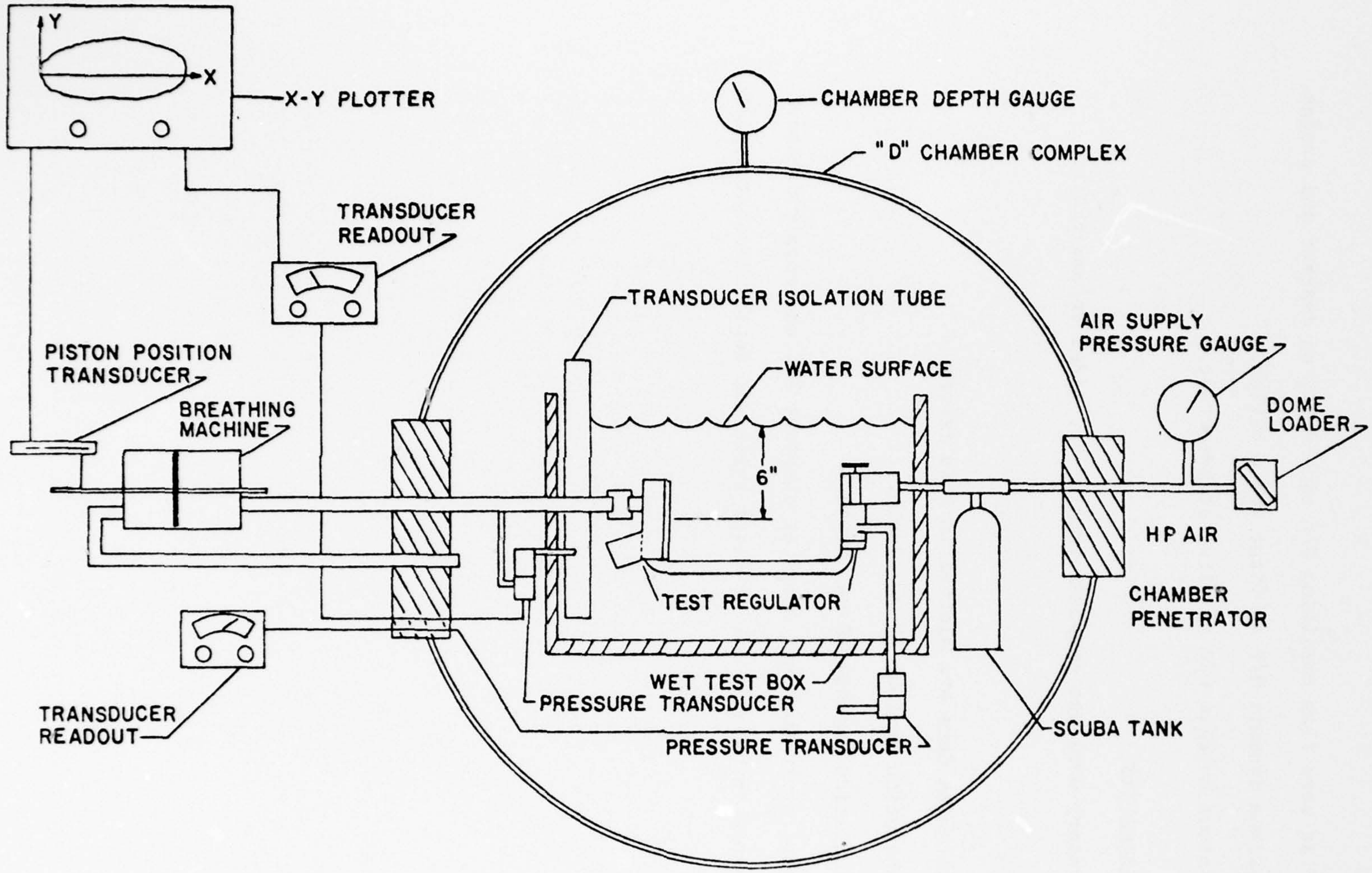


FIGURE 1. TEST SETUP
(Test Equipment is Described in Appendix B)

4. ΔP at zero flow condition for each depth on descent and ascent.

5. Maximum dynamic O/B at first stage outlet.

6. Minimum dynamic O/B at first stage outlet.

COMPUTED PARAMETERS

Respiratory work was computed from ΔP vs. tidal volume plots.

DATA PLOTTED

The following data are plotted in this report.

1. Inhalation maximum ΔP vs. depth.

2. Exhalation maximum ΔP vs. depth.

3. Respiratory work vs. depth at constant RMV and supply pressure.

4. Change in dynamic O/B at first stage vs. depth at constant RMV.

RESULTS AND DISCUSSION

DESCRIPTION

The MR12-II regulator has a balanced, diaphragm-type first stage with two low-pressure ports and one high-pressure port for a submersible pressure gauge. The downstream second stage has a unique bypass tube that differentiates it from its predecessor, the MR12. The bypass tube directs the air from the valve seat directly to the mouthpiece, completely bypassing the diaphragm area. The bypass tube and deflector baffle mounted in the mouthpiece create a high-velocity, low-pressure area (vortex) in the mouthpiece tube to assist in movement of the second-stage diaphragm. Diaphragm movement, in turn, actuates the valve mechanism. Theoretically, the harder a diver works, the greater the "vortex assist."

BREATHING RESISTANCE TESTS

Breathing resistance was measured at three RMV's to simulate light, moderate, and heavy diver work rates. Light work was measured at 22.5 RMV (1.5-liter tidal volume and 15 bpm), moderate work was measured at 40 RMV (2.0-liter tidal volume and 20 bpm), and heavy work was measured at 75 RMV (3.0-liter tidal volume and 25 bpm). The mil spec (reference 1) calls for only 40 RMV at 1000-psig supply pressure. However, the other RMV's were measured to evaluate regulator performance more fully.

The breathing resistances plotted in the figures are the maximum resistances measured (except for cracking pressure) during one complete exhalation-inhalation cycle at the specified depth and RMV. Air supply pressure to the first stage was 1000 psig. Resistance was measured at 500

psig O/B and 200 psig O/B supply pressures on the surface and at 200 fsw at each RMV. The mil spec does not require the 300-fsw data; however, this information was obtained to demonstrate regulator performance at extreme depths.

The following table lists equivalent depth densities for air vs. HeO_2 down to 300 fsw on air. This table is a means of comparing regulator performance on HeO_2 mixes at depths greater than 200 fsw.

Air Depth (fsw)	Equivalent HeO_2 Depth (fsw)
50	230
100	625
150	1000
200	1350
250	1725
300	2075

NOTE

Figures that do not have complete data to 300 fsw were terminated at the maximum indicated depth because of excessive breathing resistance.

Inhalation Characteristics

Inhalation resistances plotted are the maximum pressures recorded at all RMV's. In most cases, the maximum pressures occurred just after flow was initiated. As the inhalation cycle continued, resistance

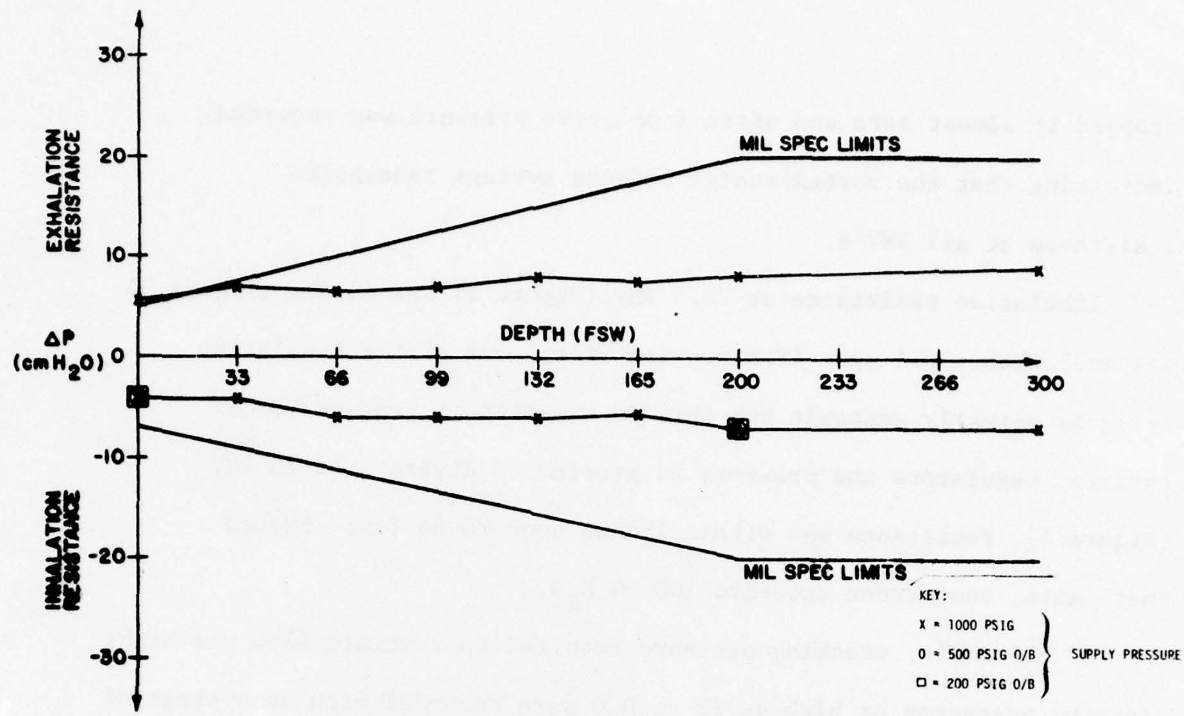


FIGURE 2. BREATHING RESISTANCE VS. DEPTH FOR MR12-II REGULATOR AT 15 BPM, 1.5 TIDAL VOLUME, AND 22.5 RMV

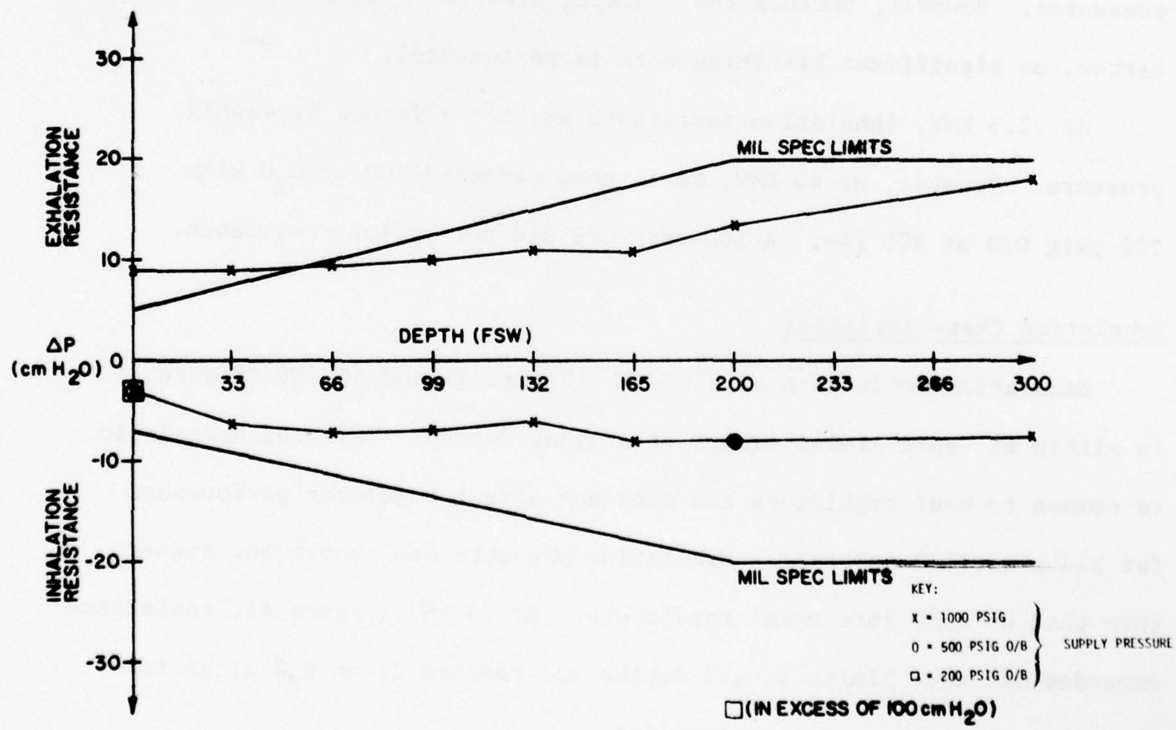


FIGURE 3. BREATHING RESISTANCE VS. DEPTH FOR MR12-II REGULATOR AT 20 BPM, 2.0 TIDAL VOLUME, AND 40 RMV

dropped to almost zero and often a positive pressure was recorded, indicating that the vortex-assist reduces average inhalation resistance at all RMV's.

Inhalation resistance at 22.5 RMV (Figure 2) and 40 RMV (Figure 3) was well within mil spec limits. The first part of the inhalation cycle is slightly unstable but this is expected of venturi/vortex assisted regulators and presents no problem to divers. At 75 RMV (Figure 4), resistance was within limits down to 66 fsw. Beyond that depth, resistance exceeded 100 cm H_2O.

At all RMV's, cracking pressure required to initiate flow was high; cracking pressures as high as 22 cm H_2O were recorded with an average of 15 cm H_2O. Most late-model regulators average 6 to 8 cm H_2O cracking pressures. However, because the cracking pressure spikes were extremely narrow, no significant breathing work is represented.

At 22.5 RMV, inhalation resistance was not affected by supply pressure. However, at 40 RMV, resistance exceeded 100 cm H_2O with 200 psig O/B at 200 fsw. A 500-psig O/B did not affect resistance.

Exhalation Characteristics

Exhalation resistance at 22.5 RMV (Figure 2) and 40 RMV (Figure 3) is within mil spec limits except at shallow depths. This characteristic is common to most regulators and does not affect regulator performance for all practical purposes. Exhalation pressure was smooth but higher than that of many late model regulators. At 75 RMV (Figure 4), resistance exceeded mil spec limits at all depths and reached 22 cm H_2O at 99 fsw. The test was terminated at this point.

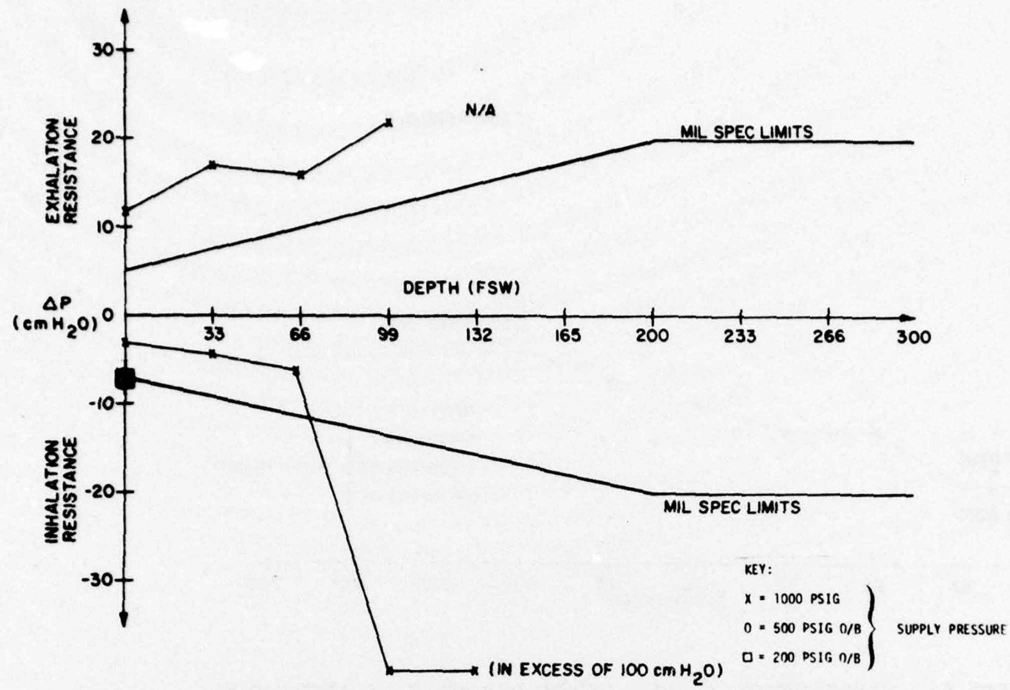


FIGURE 4. BREATHING RESISTANCE VS. DEPTH FOR MR12-II REGULATOR AT 25 BPM, 3.0 TIDAL VOLUME AND 75 RMV

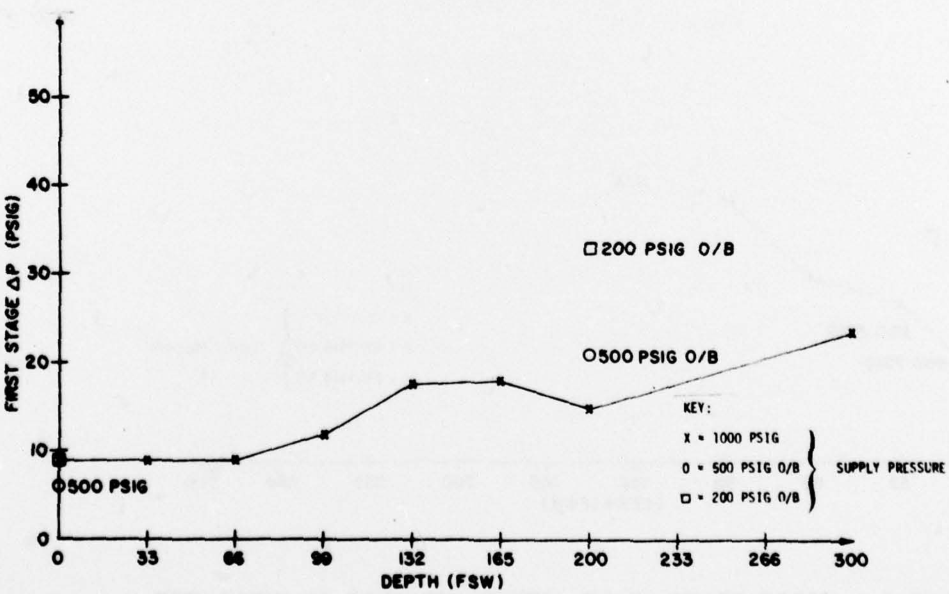


FIGURE 5. FIRST STAGE ΔP VS. DEPTH FOR MR12-II REGULATOR AT 15 BPM, 1.5 TIDAL VOLUME, AND 22.5 RMV

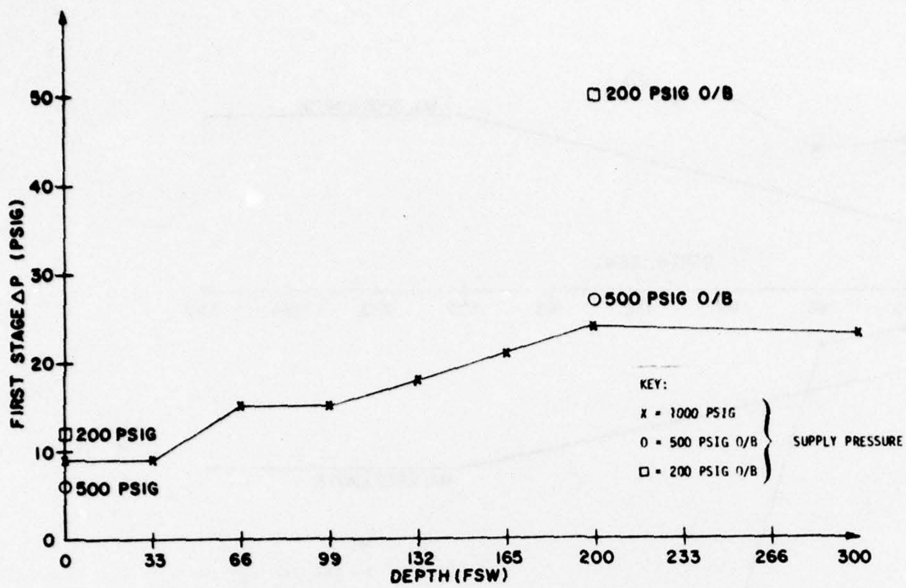


FIGURE 6. FIRST STAGE ΔP VS. DEPTH FOR MR12-II REGULATOR AT 20 BPM, 2.0 TIDAL VOLUME, AND 40 RMV

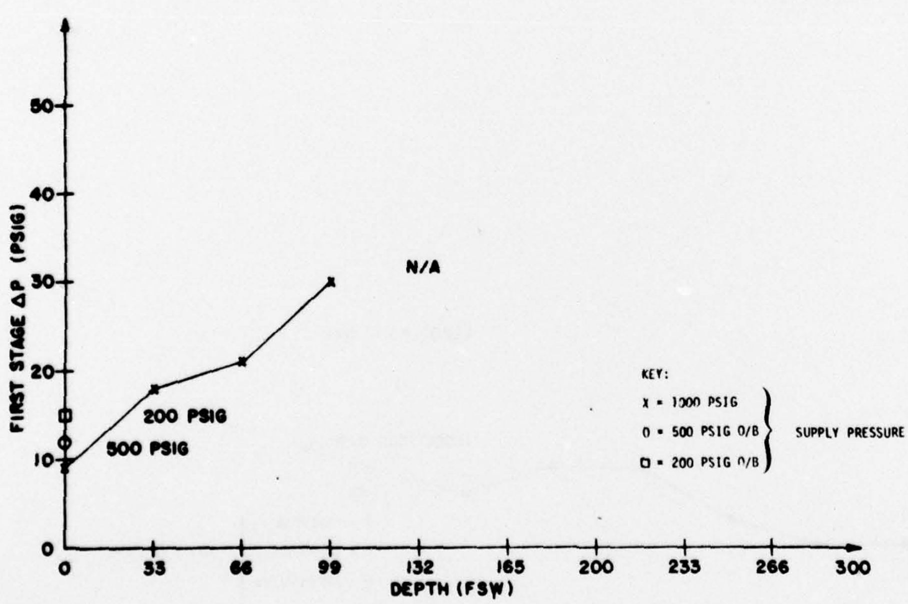


FIGURE 7. FIRST STAGE ΔP VS. DEPTH FOR MR12-II REGULATOR AT 25 BPM, 3.0 TIDAL VOLUME, AND 75 RMV

FIRST STAGE PERFORMANCE

Intermediate pressure drop under flow conditions between the first and second stages was monitored to evaluate regulator performance at a given RMV and depth. Maximum intermediate pressure drop from the static setting was plotted. By correlating this information with the breathing resistance plots, poor regulator performance can be traced to the first stage, second stage, or both stages.

The factory-set static pressure on the first stage is 130-psig O/B. At 22.5 RMV (Figure 5), first stage pressure drop was low, as the maximum drop was to only 18 psig less than the static setting. At 40 RMV (Figure 6), the maximum pressure drop of 24 psig at 200 fsw was still within first-stage operating range. However, when supply pressure was reduced to 200 psig O/B at 200 fsw, first-stage ΔP reached 50 psig, causing excessive inhalation resistance. The MR12-II regulator second stage cannot operate at 50 psig less than the factory setting.

At 75 RMV (Figure 7), ΔP increased rapidly with depth, reaching 30-psig pressure drop at 99 fsw. This pressure corresponds to an inhalation resistance of 40 cm H_2O. The slope of the graph shows that the first stage was not designed to operate at heavy work rates except in shallow water.

WORK OF BREATHING

The specification governing testing of all breathing apparatuses cites peak inhalation and peak exhalation pressures as the standards for evaluation (reference 2). However, recent research (reference 3) has shown that measurement of a diver's external respiratory work in operating

his breathing apparatus yields useful data for evaluating equipment performance. With open-circuit scuba, breathing work is a supplementary indicator of regulator performance. Reference 3 proposes a standard of 0.170 kilogram-meter per liter ventilation (kg·m/l; liter ventilation is defined as tidal volume at a given RMV) as the maximum allowable external respiratory work. This figure is used in this report for comparative purposes only. Breathing work is defined as the area enclosed by a typical pressure-volume loop generated during one complete breathing cycle.

Breathing work (Figure 8) is low for 22.5 and 40 RMV. The maximum measured at 40 RMV at 200 fsw was well below the proposed standard. At 75 RMV, the required breathing work stayed below the proposed standard to 75 fsw. It is significant that although breathing resistance at 75 RMV (see Figure 4) is outside of mil spec limits at all depths, the work of breathing required of the diver is acceptable to 75 fsw.

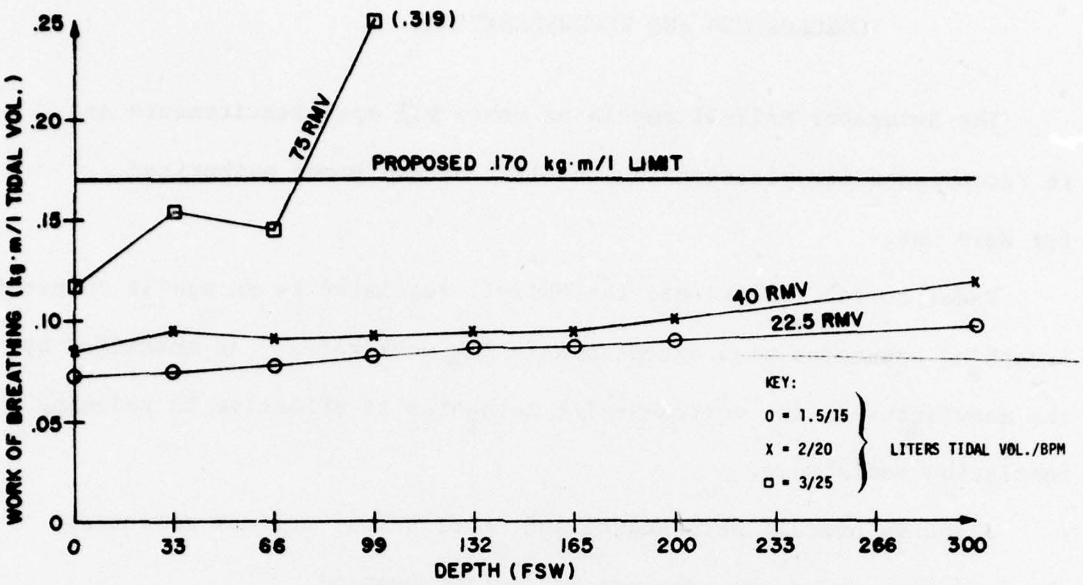


FIGURE 8. BREATHING WORK VS. DEPTH FOR MR12-II REGULATOR AT 1000-PSIG SUPPLY PRESSURE

CONCLUSIONS AND RECOMMENDATIONS

The Swimaster MR12-II regulator meets mil spec requirements and is recommended for placement on the list of equipment authorized for Navy use.

Under normal conditions, the MR12-II regulator is an easily operated breathing apparatus with exceptionally low work rates. As specified by the manufacturer, the vortex-assist mechanism is effective in reducing inhalation resistance.

Although overall performance and diver safety are not affected, the following areas are recommended for improvement.

a. Exhalation Resistance. Tests revealed that exhalation resistance was high under all test conditions, especially when compared with inhalation resistance. Enlarging the exhaust port to 1 inch diameter is recommended. (The MR12-II exhaust port is identical to that of the MR12.)

b. Cracking Pressure. Cracking pressure on inhalation is much higher than required with most other late model regulators. Changes to the second-stage diaphragm and linkage assembly are recommended to correct the problem.

REFERENCES

1. Department of the Navy Military Specification MIL-R-24169A, Regulator, Air, Demand, Single Hose, Nonmagnetic, Divers, 22 March 1967.

2. Navy Experimental Diving Unit Report 23-73, U.S.N. Procedures for Testing the Breathing Characteristics of Open-Circuit Scuba Regulators, by S.D. Reimers, p. 5, 11 December 1973.

3. Navy Experimental Diving Unit Report 19-73, Proposed Standards for the Evaluation of the Breathing Resistance of Underwater Breathing Apparatus, by S.D. Reimers, p. 36, 30 January 1974.

APPENDIX A

TEST PLAN

The plan for testing the Swimaster MR12-II Regulator consisted of the following steps.

1. Insure that the regulator is set to factory specifications and is working properly.
2. Insure that the chamber is on the surface.
3. Calibrate the transducers and zero the transducers by regulator position after water is added to the wet test box.
4. Open the air supply valve to test the regulator and set the supply pressure at 1000 psig.
5. Adjust the breathing machine to 1.5-liter tidal volume and 15 BPM and take readings.
6. Stop the breathing machine.
7. Establish zero flow ΔP position on the x-y plotter.
8. Adjust the air supply pressure to 500 psig O/B.
9. Repeat steps 5 through 7.
10. Adjust the air supply pressure to 200 psig O/B. (Be sure that the breathing resistance transducer stays within its range.)
11. Repeat steps 5 through 7.
12. Pressurize the chamber to 33 fsw.
13. Adjust the air supply to 1000 psig.
14. Repeat steps 5 through 7.
15. Pressurize the chamber to 55 fsw.
16. Adjust the air supply to 1000 psig.
17. Repeat steps 5 through 7.
18. Pressurize the chamber to 99 fsw.
19. Adjust the air supply to 1000 psig.
20. Repeat steps 5 through 7.

21. Pressurize the chamber to 132 fsw.

22. Adjust the air supply to 1000 psig.

23. Repeat steps 5 through 7.

24. Pressurize the chamber to 165 fsw.

25. Adjust the air supply to 1000 psig.

26. Repeat steps 5 through 7.

27. Pressurize the chamber to 200 fsw.

28. Repeat steps 4 through 11.

29. Pressurize the chamber to 300 fsw.

30. Adjust the air supply to 1000 psig.

31. Repeat steps 5 through 7.

32. Set the breathing machine to 2.0-liter tidal volume and 20 BPM. (This replaces step 5.)

33. Repeat steps 4 through 31 in reverse order (as chamber is being brought to surface, make incremental stops in reverse order.)

34. Set the breathing machine to 3.0-liter tidal volume and 25 BPM. (This replaces step 5.)

35. Repeat steps 4 through 31.

36. Bring the chamber to the surface (no stops).

37. Check the transducer calibration.

APPENDIX B

TEST EQUIPMENT

The following equipment was used in testing the Swimaster MR12-II Regulator. The equipment setup is shown in Figure 1.

1. NEDU breathing machine.

2. Validyne model DP-15 pressure transducer with 1-psid diaphragm.

3. NEDU wet test box.

4. Validyne model DP-15 pressure transducer with 250-psid diaphragm.

5. MFE x-y plotter, model 715M, serial number 30925002.

6. Validyne model CD-12 transducer readouts (2), serial numbers 12247 and 5538.

7. 71.2-cu. ft. scuba tank.

8. NEDU "D" chamber complex.

9. Roylyn air supply pressure gauge, model 0 to 2000 psig with accuracy to 0.25 percent; calibration date, August, 1976.

10. Marotta dome loader.

11. Roylyn chamber depth gauge, model 0 to 2300 fsw with accuracy to 0.25 percent; calibration date, December, 1975.

12. Test regulator (first and second stage), Swimaster MR12-II serial number B31234.

13. Bourns piston position transducer, model 200176400B.

14. Transducer isolation tube.

APPENDIX C

MAN-HOURS REQUIRED

The man-hours required for the test of the Swimaster MR12-II Regulator are computed below.

	Men	Hours	Man-Hours
Test setup	3	2	6
Test operation	3	2	6
Chamber operation	3	2	6
Post-test cleanup	2	1	2
Data reduction/report production	1	80	80
Duplicating	4	25	100
TOTAL			200